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	Eurocode Ref	EN 1991-1-2:2002		
	Made by	Z Sokol	Date	Jan 2006
	Checked by	F Wald	Date	Jan 2006

Example: Parametric fire curve for a fire compartment

This example shows the determination of the parametric fire curve for a fire compartment in an office building, according to Annex A of EN 1991-1-2. The walls and the floors above and below the compartment are of reinforced concrete; the walls have several openings. Reference is made to SD006 for the thermal properties of the walls and floors.

Basic data

Dimensions of the fire compartment

width: $a = 8,5$ m

length: $b = 10,0$ m

height: $h = 3,15$ m

height of opening $h_{op} = 1,537$ m

width of opening $b_{op} = 3,85$ m

number of openings $n = 4$; see **Figure 1.**

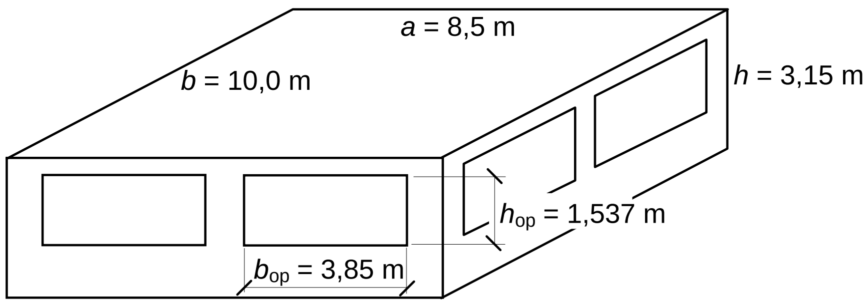

Figure 1: Considered fire compartment

The floor and ceiling are made from reinforced concrete

density $\rho = 2300$ kg m^{-3} SD006

specific heat $c = 840$ J kg^{-1} K^{-1}

thermal conductivity $\lambda = 1,57$ W m^{-1} K^{-1}

The walls are made from lightweight concrete

density $\rho = 500$ kg m^{-3} SD006

specific heat $c = 840$ J kg^{-1} K^{-1}

thermal conductivity $\lambda = 0,22$ W m^{-1} K^{-1}

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Fire load density

For office buildings, the characteristic fire load density related to floor area, for the 80% fractile case (Gumbel distribution) is given by Table E.4 as:

EN 1991-1-2 Annex E Table E.4

$q_{f,k} = 511$ MJ m^{-2}

The floor area is

$$A_f = a\, b = 8{,}5 \cdot 10{,}0 = 85 \text{ m}^2$$

The factor to take into account the fire activation risk due to the size of the compartment is given by linear interpolation from Table E.1:

EN 1991-1-2 Annex E Table E.1

$$\delta_{q1} = 1{,}1 + (1{,}5 + 1{,}1) \cdot (85 - 25)/(250 - 25) = 1{,}20$$

For the factor to take into account the fire activation risk due to the type of occupancy δ_{q2} =1,00.

The factor to take into account the different fire fighting measures δ_n = 1,00

The design fire load density is given by:

$$q_{f,d} = q_{f,k}\delta_{q1}\delta_{q2}\delta_n$$

$$= 511 \cdot 1{,}20 \cdot 1{,}00 \cdot 1{,}00 = 613 \text{ MJ m}^{-2}$$

Thermal properties of the fire compartment

The total area of the enclosure is:

$$A_t = 2\, A_f + 2\,(a + b)\, h = 2 \cdot 85 + 2 \cdot (8{,}5 + 10{,}0) \cdot 3{,}15 = 286{,}55 \text{ m}^2$$

The total area of vertical openings is:

$$A_v = n\, h_{op}\, b_{op} = 4 \cdot 1{,}537 \cdot 3{,}85 = 23{,}67 \text{ m}^2$$

The surface factor for floor and ceiling is:

EN 1991-1-2 Annex A

$$b = \sqrt{\rho\, c\, \lambda} = \sqrt{2300 \cdot 840 \cdot 1{,}57} = 1742 \text{ J m}^{-2}\text{s}^{-0,5}\text{K}^{-1}$$

The surface factor for walls is:

$$b = \sqrt{\rho\, c\, \lambda} = \sqrt{500 \cdot 840 \cdot 0{,}22} = 304 \text{ J m}^{-2}\text{s}^{-0,5}\text{K}^{-1}$$

Both values are within the limit 100 $\leq b \leq$ 2200.

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The resulting surface factor is

$$b = \frac{\sum (b_i\ A_i)}{A_t - A_v} =$$

$$= \frac{2 \cdot 85 \cdot 7 \cdot 1742 + (2 \cdot (8,5 + 10,0) \cdot 3,15 - 23,67) \cdot 304}{286,55 - 23,67} = 1234 \text{ J m}^{-2}\text{s}^{-0,5}\text{K}^{-1}$$

Ventilation properties of the fire compartment

The opening factor is:

$$O = \frac{A_v \cdot \sqrt{h_{eq}}}{A_t} = \frac{23,67 \cdot \sqrt{1,537}}{286,55} = 0,1024 \text{ m}^{0,5}$$

where the weighted average height of the openings h_{eq} = 1,537 m.

The opening factor should be within the limits $0,02 \leq O \leq 0,2$ [$m^{0,5}$]. The limitation is satisfied.

EN 1991-1-2 Annex A(3)

Time factor function

The Γ factor is given by:

$$\Gamma = \frac{\left(\frac{O}{b}\right)^2}{\left(\frac{0,04}{1160}\right)^2} = \frac{\left(\frac{0,1024}{1234}\right)^2}{\left(\frac{0,04}{1160}\right)^2} = 5,791$$

Fire load density related to surface area

The design fire load density related to the surface area is given by:

$$q_{t,d} = \frac{q_{f,d}\ A_f}{A_t} = \frac{613 \cdot 85}{286,55} = 181,8 \text{ MJ m}^{-2}$$

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Evaluation of the limiting time and maximum temperature

Medium fire growth rate is expected, with $t_{\mathrm{lim}} = 20$ min = 0,333 hour.

The time $t_{\max}$ to reach the maximum temperature is given by:

$$t_{\max} = \max \begin{Bmatrix} \dfrac{0{,}2 \cdot 10^{-3}\ q_{\mathrm{t,d}}}{O} \\ t_{\mathrm{lim}} \end{Bmatrix} = \max \begin{Bmatrix} \dfrac{0{,}2 \cdot 10^{-3} \cdot 181{,}8}{0{,}1024} \\ 0{,}333 \end{Bmatrix} = 0{,}355 \text{ hour}$$

The fire is ventilation-controlled. because $t_{\max}$ is given by the first term.

The time to reach maximum temperature, taking account of the openings and thermal absorptivity, $t^{*}_{\max}$ is given by:

$$t^{*}_{\max} = t_{\max}\ \Gamma = 0{,}355 \cdot 5{,}791 = 2{,}056 \ \text{ hour}$$

and the maximum gas temperature is given by:

$$\theta_{\max} = 20 + 1325 \left(1 - 0{,}324\ e^{-0{,}2 \cdot 2{,}056} - 0{,}204\ e^{-1{,}7 \cdot 2{,}056} - 0{,}472\ e^{-19 \cdot 2{,}056}\right) = \\ = 1052 °\mathrm{C}$$

The curve in the heating phase

The gas temperature in the heating phase is given by

$$\theta_{\mathrm{g,t}} = 20 + 1325 \left(1 - 0{,}324\ e^{-0{,}2\, t^{*}} - 0{,}204\ e^{-1{,}7\, t^{*}} - 0{,}472\ e^{-19\, t^{*}}\right)$$

where the time t^{*} is given by:

$$t^{*} = t\ \Gamma = 5{,}791\ t$$

The curve in the cooling phase

For $t^{*}_{\max} > 2$ hours, the gas temperature in the cooling phase is given by:

$$\theta_{\mathrm{g,t}} = \theta_{\max} - 250 \left(t^{*} - t^{*}_{\max}\ x\right) = \\ = 1052 - 250 \cdot \left(t^{*} - 2{,}056 \cdot 1\right) = \\ = 1566 - 250 \cdot t^{*}$$

where the factor $x = 1$ for a ventilation-controlled fire.

The resulting parametric curve is shown in ***Figure 2***.

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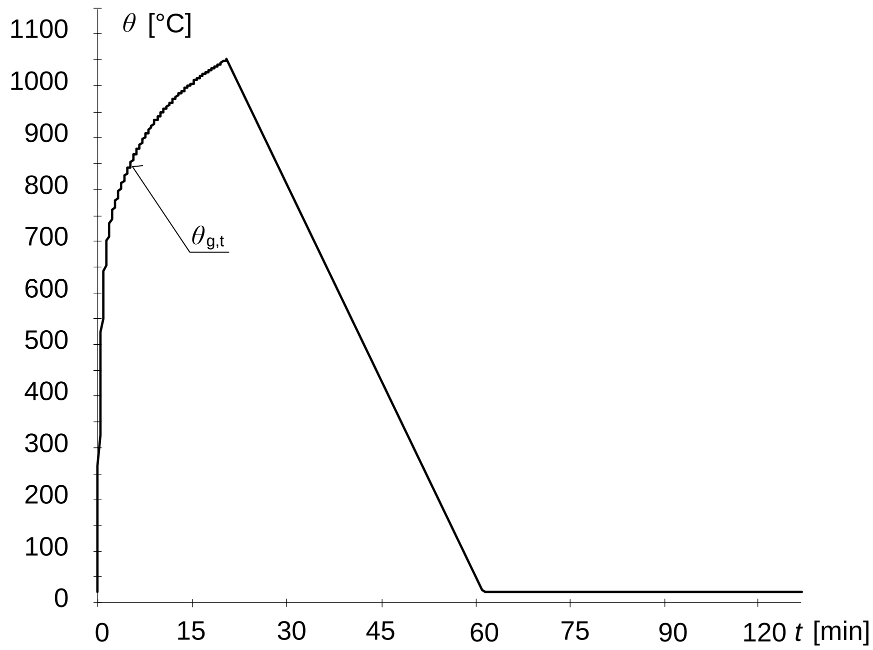

Figure 2: Gas temperature-time curve

Quality Record

RESOURCE TITLE	Example: Parametric fire curve for a fire compartment		
Reference(s)			
ORIGINAL DOCUMENT			
	Name	**Company**	**Date**
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